CLAIMS

1. An apparatus used in a communication node in a packet-switched data communication network wherein the communication node serves as a home agent for mobile routers so that a bi-directional tunnel is established between the home agent and the mobile router through which packets sent to the mobile network behind the mobile router are intercepted by the home agent and forwarded to the mobile router through the bi-directional tunnel, and packets sent by nodes from the mobile network are intercepted by the mobile router and forwarded to the home agent through the bi-directional tunnel to be further routed to the appropriate destination, the apparatus comprising:

an Incoming Packet Processor that processes all incoming packets for standard networking protocol processing, and passing packets to different components once the types of the incoming packets are identified;

an Outgoing Packet Processor that performs all processing required before sending a packet out to physical media;

a Binding Manager that maintains the binding between home-address and care-of-addresses of registered mobile nodes, and also handles data packets received by

the Incoming Packet Processor that are identified to be related to binding of registered mobile routers' addresses;

a Route Manager that maintains the routing information and handles routing update messages that are received by the Incoming Packet Processor;

a Configuration Interface that provide configuration information about the home agent and all its legal mobile router users; and

a Forwarding Unit that is responsible for the routing of packets to other nodes.

2. The apparatus according to claim 1, wherein the Configuration Interface loads the information from a secondary storage during system boot-up, and reloads the information when it detects that such information has been modified.

3. The apparatus according to claim 1, wherein the Configuration Interface retrieves the configuration information based on input for adapting configuration parameters from a human administrator in real time.

4. The apparatus according to claim 1, wherein the Configuration Interface loads the configuration

information from a remote central database.

5. The apparatus according to claim 1, wherein the Configuration Interface queries a remote central database when it receives configuration parameter query from other components and fetches the information from the remote central database to be returned to the original component that makes the enquiry.

6. The apparatus according to claim 1, wherein the Configuration Interface further provides the following specific set of configuration parameter relating to the home agent:

(i) information on whether dynamic routing protocol is enabled for mobile routers that are away from home;

(ii) maximum lifetime of binding cache entries;

(iii) maximum lifetime of routing table entries;

(iv) lifetime of a binding cache entry to use when it is unclear whether a dynamic routing protocol will be run by an away mobile router; and

(v) maximum number of Binding Update messages to accept while it is unclear whether a dynamic routing protocol will be run by an away mobile router.

7. The apparatus according to claim 1, wherein the

Configuration Interface further provides the following specific set of configuration parameter for each mobile router that is a legal user of the home agent:

(i) information on security associations of mobile router (such as pre-established security key associated to the mobile router);

(ii) information on whether the particular mobile router is authorized to run dynamic routing protocols;

(iii) type of dynamic routing protocols the mobile router is authorized to run;

(iv) the set of default network prefixes that are associated to the mobile router;

(v) range of network prefixes that can be legally associated to the mobile router; and

(vi) default action to be taken when the prefix information contained in a binding update message is in conflict or inconsistent with the routing information sent by the mobile router.

8. The apparatus according to claim 1, wherein the Binding Manager further maintains the following information about each registered mobile router:

(i) home-address of the mobile router;

(ii) care-of-address of the mobile router;

(iii) the mode (implicit or explicit) of the last

successful binding update message received from the mobile router;

(iv) the time at which this set of information will expire;

(v) prefix information contained in the last successful binding update message received; and

(vi) the number of binding update messages received from the mobile router while it is still unclear whether a dynamic routing protocol will be run by the mobile router.

9. The apparatus according to claim 1 wherein the Binding Manager temporarily accepts binding update from a mobile router that does not explicitly specifies any mobile network prefix and does not have a default associated network prefix to wait for the mobile router to run a dynamic routing protocol by specifying a short Lifetime value in the binding acknowledgement, and rejects subsequent binding updates if the mobile router fail to send prefix information using a dynamic routing protocol after a pre-determined period of time since the first binding update is accepted.

10. The apparatus according to claim 1 wherein the Binding Manager temporarily accepts binding update from

a mobile router that explicitly specifies a single or plurality of mobile network prefix to wait for the mobile router to run a dynamic routing protocol by specifying a short Lifetime value in the binding acknowledgement, and rejects subsequent binding updates if any of the explicitly specified prefixes is in conflict with the routes installed by routing update messages sent from the mobile router running a dynamic routing protocol, or accepts subsequent binding updates with normal Lifetime values if there is no such conflict after a pre-determined period of time since the first binding update is accepted.

11. A method for processing binding update message received by a mobile router's home agent which includes an apparatus used in a communication node in a packet-switched data communication network wherein the communication node serves as a home agent for mobile routers so that a bi-directional tunnel is established between the home agent and the mobile router through which packets sent to the mobile network behind the mobile router are intercepted by the home agent and forwarded to the mobile router through the bi-directional tunnel, and packets sent by nodes from the mobile network are intercepted by the mobile router and

forwarded to the home agent through the bi-directional tunnel to be further routed to the appropriate destination, the apparatus comprising: an Incoming Packet Processor that processes all incoming packets for standard networking protocol processing, and passing packets to different components once the types of the incoming packets are identified; an Outgoing Packet Processor that performs all processing required before sending a packet out to physical media; a Binding Manager that maintains the binding between home-address and care-of-addresses of registered mobile nodes, and also handles data packets received by the Incoming Packet Processor that are identified to be related to binding of registered mobile routers' addresses; a Route Manager that maintains the routing information and handles routing update messages that are received by the Incoming Packet Processor; a Configuration Interface that provide configuration information about the home agent and all its legal mobile router users; and a Forwarding Unit that is responsible for the routing of packets to other nodes, wherein the binding update message does not contain any mobile network prefix information comprising the steps of

checking if the mobile router is authorized to run dynamic routing protocol;

whereas if the mobile router is not authorized to run dynamic routing protocol, sending back a negative acknowledgement if there is no default network prefix associated with the mobile router;

whereas if the mobile router is not authorized to run dynamic routing protocol, sending back a positive acknowledgement if there is a single or plurality of default network prefix associated with the mobile router, updating the binding information in the Binding Manager, and installing routes to the default network prefixes in the Route Manager;

whereas if the mobile router is authorized to run dynamic routing protocol, consulting the Route Manager if the mobile router has already sent routing update messages;

whereas if the mobile router is authorized to run dynamic routing protocol and has sent routing update messages to the home agent, sending back a positive acknowledgement and updating the binding information in the Binding Manager;

whereas if the mobile router is authorized to run dynamic routing protocol but has not sent routing update messages to the home agent, sending back a positive acknowledgement with a small Lifetime value and updating the binding information in the Binding Manager if the

number of binding update messages received from the mobile router is less than a pre-determined positive number; and

whereas if the mobile router is authorized to run dynamic routing protocol but has not sent routing update messages to the home agent, sending back a negative acknowledgement and removing the binding information in the Binding Manager if the number of binding update messages received from the mobile router is greater than or equal to a pre-determined positive number.

12. A method for error recovery when processing binding update message received by a mobile router's home agent which includes an apparatus used in a communication node in a packet-switched data communication network wherein the communication node serves as a home agent for mobile routers so that a bi-directional tunnel is established between the home agent and the mobile router through which packets sent to the mobile network behind the mobile router are intercepted by the home agent and forwarded to the mobile router through the bi-directional tunnel, and packets sent by nodes from the mobile network are intercepted by the mobile router and forwarded to the home agent through the bi-directional tunnel to be further routed to the appropriate

destination, the apparatus comprising: an Incoming Packet Processor that processes all incoming packets for standard networking protocol processing, and passing packets to different components once the types of the incoming packets are identified; an Outgoing Packet Processor that performs all processing required before sending a packet out to physical media; a Binding Manager that maintains the binding between home-address and care-of-addresses of registered mobile nodes, and also handles data packets received by the Incoming Packet Processor that are identified to be related to binding of registered mobile routers' addresses; a Route Manager that maintains the routing information and handles routing update messages that are received by the Incoming Packet Processor; a Configuration Interface that provide configuration information about the home agent and all its legal mobile router users; and a Forwarding Unit that is responsible for the routing of packets to other nodes, wherein the binding update message contains a single or plurality of mobile network prefix information that is in conflict with the routes installed by the dynamic routing protocol run by the mobile router, comprising the steps of:

checking configured error behavior in the configuration information for the mobile router;

if the configured error behavior is to tear down the bi-directional tunnel, sending the mobile router a negative binding acknowledgment, removing binding information related to the mobile router in the Binding Manager and removing all routes installed by the mobile router from the Route Manager;

if the configured error behavior is to silently ignore the prefix specified in the binding update message, sending the mobile router a positive binding acknowledgment and updating the binding information related to the mobile router in the Binding Manager;

if the configured error behavior is to ignore the prefix specified in the binding update message with a warning, sending the mobile router a positive binding acknowledgment with a special option indicating the prefix is ignored and updating the binding information related to the mobile router in the Binding Manager;

if the configured error behavior is to silently ignore the routes installed using dynamic routing protocol, sending the mobile router a positive binding acknowledgment, updating the binding information related to the mobile router in the Binding Manager, removing all routes installed by the mobile router from the mobile router and installing routes in the Route Manager based on the prefix information specified in the binding

update message; and

if the configured error behavior is to ignore the routes installed using dynamic routing protocol with a warning, sending the mobile router a positive binding acknowledgment, updating the binding information related to the mobile router in the Binding Manager, removing all routes installed by the mobile router from the mobile router, installing routes in the Route Manager based on the prefix information specified in the binding update message, and instructing the Route Manager to inform the mobile router of the changes in routes using the dynamic routing protocol.

13. A method for processing binding update message received by a mobile router's home agent which includes an apparatus used in a communication node in a packet-switched data communication network wherein the communication node serves as a home agent for mobile routers so that a bi-directional tunnel is established between the home agent and the mobile router through which packets sent to the mobile network behind the mobile router are intercepted by the home agent and forwarded to the mobile router through the bi-directional tunnel, and packets sent by nodes from the mobile network are intercepted by the mobile router and

forwarded to the home agent through the bi-directional tunnel to be further routed to the appropriate destination, the apparatus comprising: an Incoming Packet Processor that processes all incoming packets for standard networking protocol processing, and passing packets to different components once the types of the incoming packets are identified; an Outgoing Packet Processor that performs all processing required before sending a packet out to physical media; a Binding Manager that maintains the binding between home-address and care-of-addresses of registered mobile nodes, and also handles data packets received by the Incoming Packet Processor that are identified to be related to binding of registered mobile routers' addresses; a Route Manager that maintains the routing information and handles routing update messages that are received by the Incoming Packet Processor; a Configuration Interface that provide configuration information about the home agent and all its legal mobile router users; and a Forwarding Unit that is responsible for the routing of packets to other nodes, wherein the binding update message contains a single or plurality of mobile network prefix information comprising the steps of:

sending back a negative acknowledgement and removing the binding information in the Binding Manager

if the prefix information specified in the binding update message is invalid;

whereas if the prefix information specified in the binding update message is valid and the mobile router is not authorized to run a dynamic routing protocol, sending back a positive acknowledgement, updating the binding information in the Binding Manager, and installing routes in the Route Manager based on the prefix information specified in the binding update message;

whereas if the prefix information specified in the binding update message is valid and the mobile router is authorized to run dynamic routing protocol, consulting the Route Manager if the mobile router has already sent routing update messages;

whereas if the prefix information specified in the binding update message is valid and the mobile router is authorized to run dynamic routing protocol but has not sent routing update messages to the home agent, sending back a positive acknowledgement with a small Lifetime value, updating the binding information in the Binding Manager, installing routes based on the prefix information specified in the binding update to the Route Manager if the number of binding update messages received from the mobile router is less than a pre-

determined positive number;

whereas if the prefix information specified in the binding update message is valid and the mobile router is authorized to run dynamic routing protocol but has not sent routing update messages to the home agent, sending back a positive acknowledgement with normal Lifetime value, updating the binding information in the Binding Manager, and installing routes based on the prefix information specified in the binding update to the Route Manager if the number of binding update messages received from the mobile router is greater than or equal to a pre-determined positive number;

whereas if the prefix information specified in the binding update message is valid and the mobile router has sent routing update messages to the home agent, checking with the Route Manager if the prefix information specified in the binding update message is in conflict with the routes installed by the mobile router via routing update messages;

sending back a positive acknowledgement, updating the binding information in the Binding Manager, and installing routes based on the prefix information specified in the binding update to the Route Manager if the prefix information specified in the binding update message is valid and not in conflict with the routes

installed by the mobile router via routing update messages; and

performing, if the prefix information specified in the binding update message is valid but in conflict with the routes installed by the mobile router via routing update messages, a method comprising the steps of:

checking configured error behavior in the configuration information for the mobile router;

if the configured error behavior is to tear down the bi-directional tunnel, sending the mobile router a negative binding acknowledgment, removing binding information related to the mobile router in the Binding Manager and removing all routes installed by the mobile router from the Route Manager;

if the configured error behavior is to silently ignore the prefix specified in the binding update message, sending the mobile router a positive binding acknowledgment and updating the binding information related to the mobile router in the Binding Manager;

if the configured error behavior is to ignore the prefix specified in the binding update message with a warning, sending the mobile router a positive binding acknowledgment with a special option indicating the prefix is ignored and updating the binding information

related to the mobile router in the Binding Manager;

if the configured error behavior is to silently ignore the routes installed using dynamic routing protocol, sending the mobile router a positive binding acknowledgment, updating the binding information related to the mobile router in the Binding Manager, removing all routes installed by the mobile router from the mobile router and installing routes in the Route Manager based on the prefix information specified in the binding update message; and

if the configured error behavior is to ignore the routes installed using dynamic routing protocol with a warning, sending the mobile router a positive binding acknowledgment, updating the binding information related to the mobile router in the Binding Manager, removing all routes installed by the mobile router from the mobile router, installing routes in the Route Manager based on the prefix information specified in the binding update message, and instructing the Route Manager to inform the mobile router of the changes in routes using the dynamic routing protocol..

14. A method for processing binding update message received by a mobile router's home agent which includes an apparatus used in a communication node in a packet-

switched data communication network wherein the communication node serves as a home agent for mobile routers so that a bi-directional tunnel is established between the home agent and the mobile router through which packets sent to the mobile network behind the mobile router are intercepted by the home agent and forwarded to the mobile router through the bi-directional tunnel, and packets sent by nodes from the mobile network are intercepted by the mobile router and forwarded to the home agent through the bi-directional tunnel to be further routed to the appropriate destination, the apparatus comprising: an Incoming Packet Processor that processes all incoming packets for standard networking protocol processing, and passing packets to different components once the types of the incoming packets are identified; an Outgoing Packet Processor that performs all processing required before sending a packet out to physical media; a Binding Manager that maintains the binding between home-address and care-of-addresses of registered mobile nodes, and also handles data packets received by the Incoming Packet Processor that are identified to be related to binding of registered mobile routers' addresses; a Route Manager that maintains the routing information and handles routing update messages that are received by the

Incoming Packet Processor; a Configuration Interface that provide configuration information about the home agent and all its legal mobile router users; and a Forwarding Unit that is responsible for the routing of packets to other nodes, the method comprising the steps of:

checking if the mobile router is an authorized user of the home agent and returning a negative binding acknowledgement if the mobile router is not a valid user;

whereas the mobile router is an authorized user of the home agent, sending a positive binding acknowledgement to the mobile router, deleting the binding information associated with the mobile router in the Binding Manager, and removing all routes installed by the mobile router in the Route Manager if the Lifetime field of the binding update message is zero;

whereas the mobile router is an authorized user of the home agent and the Lifetime field of the binding update message is non-zero, processing the binding update message using a method if the binding update message does not contain any network prefix information, the method comprising the steps of:

checking if the mobile router is authorized to run dynamic routing protocol;

whereas if the mobile router is not authorized to run dynamic routing protocol, sending back a negative acknowledgement if there is no default network prefix associated with the mobile router;

whereas if the mobile router is not authorized to run dynamic routing protocol, sending back a positive acknowledgement if there is a single or plurality of default network prefix associated with the mobile router, updating the binding information in the Binding Manager, and installing routes to the default network prefixes in the Route Manager;

whereas if the mobile router is authorized to run dynamic routing protocol, consulting the Route Manager if the mobile router has already sent routing update messages;

whereas if the mobile router is authorized to run dynamic routing protocol and has sent routing update messages to the home agent, sending back a positive acknowledgement and updating the binding information in the Binding Manager;

whereas if the mobile router is authorized to run dynamic routing protocol but has not sent routing update messages to the home agent, sending back a positive acknowledgement with a small Lifetime value and updating the binding information in the Binding Manager

if the number of binding update messages received from the mobile router is less than a pre-determined positive number; and

whereas if the mobile router is authorized to run dynamic routing protocol but has not sent routing update messages to the home agent, sending back a negative acknowledgement and removing the binding information in the Binding Manager if the number of binding update messages received from the mobile router is greater than or equal to a pre-determined positive number; and

whereas the mobile router is an authorized user of the home agent and the Lifetime field of the binding update message is non-zero, processing the binding update message using a method if the binding update message contains a single or plurality of network prefix information, the method comprising the steps of:

sending back a negative acknowledgement and removing the binding information in the Binding Manager if the prefix information specified in the binding update message is invalid;

whereas if the prefix information specified in the binding update message is valid and the mobile router is not authorized to run a dynamic routing protocol, sending back a positive acknowledgement,

updating the binding information in the Binding Manager, and installing routes in the Route Manager based on the prefix information specified in the binding update message;

whereas if the prefix information specified in the binding update message is valid and the mobile router is authorized to run dynamic routing protocol, consulting the Route Manager if the mobile router has already sent routing update messages;

whereas if the prefix information specified in the binding update message is valid and the mobile router is authorized to run dynamic routing protocol but has not sent routing update messages to the home agent, sending back a positive acknowledgement with a small Lifetime value, updating the binding information in the Binding Manager, installing routes based on the prefix information specified in the binding update to the Route Manager if the number of binding update messages received from the mobile router is less than a pre-determined positive number;

whereas if the prefix information specified in the binding update message is valid and the mobile router is authorized to run dynamic routing protocol but has not sent routing update messages to the home agent, sending back a positive acknowledgement with normal

Lifetime value, updating the binding information in the Binding Manager, and installing routes based on the prefix information specified in the binding update to the Route Manager if the number of binding update messages received from the mobile router is greater than or equal to a pre-determined positive number;

whereas if the prefix information specified in the binding update message is valid and the mobile router has sent routing update messages to the home agent, checking with the Route Manager if the prefix information specified in the binding update message is in conflict with the routes installed by the mobile router via routing update messages;

sending back a positive acknowledgement, updating the binding information in the Binding Manager, and installing routes based on the prefix information specified in the binding update to the Route Manager if the prefix information specified in the binding update message is valid and not in conflict with the routes installed by the mobile router via routing update messages; and

performing, if the prefix information specified in the binding update message is valid but in conflict with the routes installed by the mobile router via routing update messages, a method comprising the

steps of:

checking configured error behavior in the configuration information for the mobile router;

if the configured error behavior is to tear down the bi-directional tunnel, sending the mobile router a negative binding acknowledgment, removing binding information related to the mobile router in the Binding Manager and removing all routes installed by the mobile router from the Route Manager;

if the configured error behavior is to silently ignore the prefix specified in the binding update message, sending the mobile router a positive binding acknowledgment and updating the binding information related to the mobile router in the Binding Manager;

if the configured error behavior is to ignore the prefix specified in the binding update message with a warning, sending the mobile router a positive binding acknowledgment with a special option indicating the prefix is ignored and updating the binding information related to the mobile router in the Binding Manager;

if the configured error behavior is to silently ignore the routes installed using dynamic routing protocol, sending the mobile router a positive

binding acknowledgment, updating the binding information related to the mobile router in the Binding Manager, removing all routes installed by the mobile router from the mobile router and installing routes in the Route Manager based on the prefix information specified in the binding update message; and

if the configured error behavior is to ignore the routes installed using dynamic routing protocol with a warning, sending the mobile router a positive binding acknowledgment, updating the binding information related to the mobile router in the Binding Manager, removing all routes installed by the mobile router from the mobile router, installing routes in the Route Manager based on the prefix information specified in the binding update message, and instructing the Route Manager to inform the mobile router of the changes in routes using the dynamic routing protocol.

15. An apparatus used in a mobile router in a packet-switched data communication network wherein the mobile router establishes a bi-directional tunnel with a home agent through which packets sent to the mobile network behind the mobile router are intercepted by the home agent and forwarded to the mobile router through the bi-directional tunnel, and packet sent by nodes from the

mobile network are intercepted by the mobile router and forwarded to the home agent through the bi-directional tunnel to be further routed to the appropriate destination, the apparatus comprising:

an Incoming Packet Processor that processes all incoming packets for standard networking protocol processing, and passing packets to different components once the types of the incoming packets are identified;

an Outgoing Packet Processor that performs all processing required before sending a packet out to physical media;

a Network Mobility Protocol Unit that is responsible for handling packets related to the protocol, including encapsulating packets to be forwarded through the bi-directional tunnel, sending binding update message packets, and receiving binding acknowledgement message packets; and

a Forwarding Unit that is responsible for the routing of packets to other nodes.

16. The apparatus according to claim 15, wherein the Network Mobility Protocol Unit further maintains the following memory store to hold the following data:

(i) a counter to store the number of binding update messages the mobile router has sent to its home agent

that does not contain any prefix information;

(ii) a constant giving the maximum number of binding update messages that does not contain any prefix information to send;

(iii) a default list of mobile network prefixes the mobile router should use in the event it fails to obtain the prefix delegated by its home agent; and

(iv) the actual list of mobile network prefixes that the mobile router is using for the current bi-directional tunnel session.

17. A method for setting up a bi-directional tunnel from a mobile router which includes an apparatus used in a mobile router in a packet-switched data communication network wherein the mobile router establishes a bi-directional tunnel with a home agent through which packets sent to the mobile network behind the mobile router are intercepted by the home agent and forwarded to the mobile router through the bi-directional tunnel, and packet sent by nodes from the mobile network are intercepted by the mobile router and forwarded to the home agent through the bi-directional tunnel to be further routed to the appropriate destination, the apparatus comprising: an Incoming Packet Processor that processes all incoming packets for standard networking

protocol processing, and passing packets to different components once the types of the incoming packets are identified; an Outgoing Packet Processor that performs all processing required before sending a packet out to physical media; a Network Mobility Protocol Unit that is responsible for handling packets related to the protocol, including encapsulating packets to be forwarded through the bi-directional tunnel, sending binding update message packets, and receiving binding acknowledgement message packets; and a Forwarding Unit that is responsible for the routing of packets to other nodes, the method comprising the steps of:

sending the home agent a binding update message that does not contain any prefix information with a small Lifetime value, if the number of binding update message sent without prefix information is less than a predetermined maximum;

sending the home agent a binding update message that contains a default prefix information if the total number of binding update messages sent without prefix information is greater than or equal to a predetermined maximum;

sending the home agent a binding update message that contains a default prefix information if the home agent rejects a previously sent binding update message

that did not contain prefix information; and

sending the home agent a binding update message that contains a prefix information the mobile router received from the home agent.